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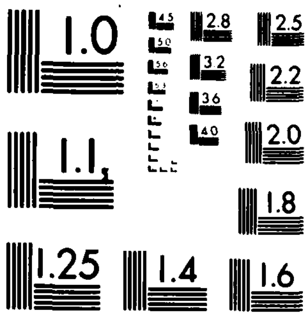

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NBDL -83R001

A HIGH-PERFORMANCE ANALOG-TO-DIGITAL CONVERSION SUBSYSTEM SUITABLE FOR THE STUDY OF EVOKED POTENTIALS, WITH DESIGN CONSIDERATIONS FOR THE ECLIPSE S140® COMPUTER

Michael D. Berger, Ph.D.

February, 1983

NAVAL BIODYNAMICS LABORATORY
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In order to evaluate impact protection devices, an impact injury model for restrained humans in a crash environment must be developed. Disruption of the functioning of the central nervous system (CNS) is an important consequence of impact injury involving the head and neck, and is an important consideration in the development of a useful impact-injury model. Ultimately, neurophysiological criteria are desired. Evoked potentials (EPs) are likely to provide appropriate neurophysiological information, but quantitative analysis of EP data presents considerable difficulty. Among the technical problems encountered is efficient

BLOCK 20 CONTINUATION

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Procedures utilizing various aspects of the design presented have been ~~employed at NBDL and~~ have been found to be effective. In the future acquisition of A/D conversion hardware, the design presented here should be considered.

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February, 1983

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SUMMARY PAGE

THE PROBLEM

In order to evaluate impact protection devices, an impact injury model for restrained humans in a crash environment must be developed. Disruption of the functioning of the central nervous system (CNS) is an important consequence of impact injury involving the head and neck, and is an important consideration in the development of a useful impact-injury model. Ultimately, neurophysiological criteria are desired. Evoked potentials (EPs) are likely to provide appropriate neurophysiological information, but quantitative analysis of EP data presents considerable difficulty. Among the technical problems encountered is efficient digitization of large amounts of EP data. This report presents detailed specifications for a high-performance analog-to-digital conversion subsystem suitable for various aspects of such work.

FINDINGS

Procedures utilizing various aspects of the design presented have been employed at NBDL and have been found to be effective.

RECOMMENDATIONS

In the future acquisition of A/D conversion hardware, the design presented here should be considered.

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TRADE NAMES

Trade names of materials or products of non-government organizations are cited where essential for precision in describing research procedures or evaluation of results. Their use does not constitute official endorsement or approval of the use of such commercial hardware or software.

PREFACE

Evoked potentials (EP's), or electrical responses of the brain to discrete stimuli, have been important in both experimental and clinical work in recent years. EP's are generally superposed on (and may interact with) other "spontaneous" electrical activity recorded from the same site. Furthermore, in many cases, the EP's themselves are known to vary considerably in amplitude, waveform, and latency of various features. For these reasons, EP data are generally digitized and studied with special and general purpose digital computers.

As part of a project to study the effects of indirect impact acceleration on the human brain at the Naval Biodynamics Laboratory in New Orleans (NBDL), a very large amount of EP data has been recorded from humans and from subhuman mammals. It has been found that very small shifts in latency, of the order of 50 microseconds or less, can be of importance, and high digitization rates were required during certain periods. In order to control cost, it was therefore necessary to develop very compact data representations, as well as high-performance analog-to-digital (A/D) conversion equipment. Salient features of the digitization procedures are:

1 - several channels are digitized simultaneously via parallel sample-and-hold hardware;

2 - the sample rate is varied as a function of time relative to each stimulus to take advantage of varying spectral content of the EP data;

3 - prior to each stimulus, data are sampled continuously at a relatively low rate to provide baseline information;

4 - the sample times following each stimulus are synchronized very accurately to the stimulus;

5 - multi-buffering is used to achieve adequate throughput;

6 - complex bookkeeping information, including time code data, accompanies the data from each EP.

At NBDL, A/D conversion procedures have been implemented on two systems. A procedure including all of the above features has been implemented on a hybrid EAI PACER® computer with excellent success. Data are recorded on frequency-multiplexed FM tape, and digitized off-line. At the same time, a simpler digitization procedure was implimented on a NOVA 800® computer. In this latter operation, data were digitized directly while the computer controlled the delivery of stimuli, and performed preliminary analysis with real-time output. The recent acquisition by the Neurophysiology Division at NBDL of an ECLIPSE S140® computer, as well as the continuing decline in cost and increase in sophistication of computer hardware, prompted the design of an A/D subsystem that would combine the advantages of both previous systems, and improve upon both. This report contains a detailed specification for this design.

The design is constructed around the ECLIPSE S140® computer, and it is assumed that the reader is familiar with the assembly language, the bus structure, and the input/output protocol of this machine. The basic design of

the A/D subsystem can, however, be easily adapted to practically any modern digital computer. It would also be possible to realize the design as a special purpose stand-alone experimental control and data acquisition facility utilizing any of several available microprocessors.

The results of experiments utilizing the implementation on the EAI PACER® computer are presented in Berger and Weiss (1983).

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#1.0 General Orientation

#1.1.0.1 Throughout this document, the numbers are decimal except where otherwise indicated.

#1.1 This document specifies a subsystem which will be used as a peripheral to a Data General Eclipse S140 based Physiological Data Acquisition System.

#1.1.1 Throughout this specification, the word "Eclipse" will refer to the Eclipse S140 located in the Neurophysiology Laboratory of the Naval Biodynamics Laboratory, New Orleans.

#1.1.2 The subsystem shall include an Eclipse-subsystem interface.

#1.1.2.1 This interface shall allow I/O instructions in the standard Eclipse format. The interface will utilize accumulator transfer, data channel transfer, pulse delivery, and map selection. The detailed functions of the instructions are described in this specification.

#1.1.2.2 Reference should be made to Data General publication 014-000629-01 for hardware specifications (including interface structure), and publication 014-000632-00 for programming considerations (including interface operation). It is noted that these publications do not contain all necessary information for the Eclipse S140. Such information will have to be obtained from from Data General, Inc., or from other sources.

#1.1.3 This document concerns hardware only. Reference to software is provided for clarification only.

#1.2 The subsystem will be used primarily in the acquisition of evoked potential (EP) data.

#1.2.1 An EP (as considered here) is the electrical response of the brain to a single, brief stimulus.

#1.2.2 The data are thus naturally divided into blocks, with one block for each stimulus. These blocks are unambiguously referred to as "sweeps" in neurophysiological jargon, and this term will be employed to avoid confusion with other types of blocks.

#1.2.3 Each sweep will start a specified amount of time before the stimulus, and continue for a specified amount of time after the stimulus.

#1.2.4 The subsystem will be organized around individual sweeps. After initialization by an Eclipse application program, the subsystem will digitize a sweep without program intervention, storing the results in the Eclipse memory as it proceeds.

#1.3 The EP data digitized by the subsystem will generally be multichannel.

#1.3.1 The subsystem will be able to sample from 1 to 8 channels simultaneously. Parallel sample and hold amplifiers will be used for this purpose.

#1.3.2 It will be possible to select, under program control, any combination of the eight available channels for simultaneous sampling, except as indicated in paragraph #1.8.2.

#1.3.3 The values obtained simultaneously from the selected channels will be referred to collectively as a "point".

#1.3.3.1 Throughout this specification, the "time a point is sampled", or "sample time" refers to the time that the sample and hold amplifiers shift to the hold state.

#1.3.4 When stored in the Eclipse memory by the subsystem, the values associated with a point will be stored contiguously in order of increasing channel number. Space shall not be left for unused channels.

#1.4 The subsystem will function in either of two mutually exclusive modes:

#1.4.0.1 "Synchronous Mode," which is primarily used when the Eclipse is controlling an experiment and acquiring digital data via the subsystem while the experiment is in progress;

#1.4.0.2 "Asynchronous Mode," which is primarily for experiments not controlled by the Eclipse, or for playback of experiments recorded on analog tape.

#1.4.1 Except where otherwise specified, the output of the subsystem to the Eclipse memory will be independent of mode.

#1.5.1 In Synchronous Mode, the subsystem will be capable of optionally triggering the stimulus that produces the EP. Pulses which are delivered by the subsystem to perform this function are called "Output Triggers".

#1.5.2 Such Output Triggers will not be deliverable in Asynchronous mode.

#1.6 The subsystem will be capable of sampling different portions of the sweep at different rates.

#1.7 Two types of parameters will be delivered from the Eclipse to the subsystem under program control: Universal Parameters; and Immediate Parameters.

#1.7.1 Universal Parameters are delivered to the subsystem via the data channel.

#1.7.2 Immediate Parameters are delivered to the subsystem via accumulator transfer.

#1.7.3 Both Universal and Immediate Parameters shall be held by the subsystem until they are modified by the Eclipse, or until there is a power loss.

#1.8 The subsystem shall be capable of digitizing up to 500,000 12 bit words per second and delivering these data as 16 bit, 2's complement words with sign extended to the Eclipse memory at this rate.

#1.8.1 Any one of the eight channels shall be capable of digitizing up to 100,000 12 bit words per second with the subsystem delivering the digitized values as 16 bit 2's complement words with sign extended to the Eclipse memory at this rate.

#1.8.2 The required maximum digitization rate of 500,000 12 bit words per second is the product of the number of channels times the digitization rate per channel. While it will be possible to select parameter combinations that would require higher rates, the subsystem need not perform at these higher rates. It is required, however, that failure to perform correctly be indicated in a

status word. (#8.0)

#2.0 Multiple Digitization Rates

#2.1 There will be a "Base Sample Interval" that will be a Universal Parameter. This interval will be the reciprocal of the fastest sample rate used in each sweep.

#2.1.1 The Base Sample Interval is specified in a 16 bit register in microseconds and may take any integer value from 10 to 65535 microseconds.

#2.1.2 Within the subsystem, the interval between any two pulses representing the Base Sample Interval shall differ from the nominal value by no more than 0.001% for any value of the Base Sample Interval.

#2.2 Each sweep will be divisible into up to seven "epochs". Some of these epochs will be "pre-stimulus" (#2.6.2), and some will be "post-stimulus" (#2.6.3).

#2.3 The sample interval (per channel) will (generally) be different in the different epochs.

#2.3.1 The sample interval for each epoch will be a (generally) different integral power of two multiplied by the Base Sample Interval. This value will be referred to as the "Sample Ratio" for the epoch.

#2.3.2 The exponent (of two) that determines the Sample Ratio is called the "Sample Ratio Exponent" and ranges from 0 to 12.

#2.3.3 The precision limits for pulses within the subsystem representing the sample intervals of each of the epochs shall be the same as the precision limits for the Base Sample Interval (#2.1.2).

#2.4 The number of points sampled in each epoch will (generally) be different.

#2.4.1 The number of points sampled in each epoch may be any integer value ranging from 0 to 4096, and will be determined by a parameter associated with the Sample Ratio Exponent for the epoch. This parameter will be called the "Epoch Interval Count" for the epoch.

#2.4.2 If the Epoch Interval Count for an epoch is specified as zero, there shall be 4096 points in that epoch. Otherwise, the number of points in the epoch shall be equal to the number specified in the Epoch Interval Count.

#2.5 The two by seven matrix of Sample Ratio Exponents and Epoch Interval Counts will be referred to as the "Epoch Specification Matrix" and will be included among the Universal Parameters.

#2.5.1 The number of epochs used shall be specified by a parameter referred to as "Epoch Number".

#2.5.2 Epoch Number shall be specified in the Immediate Parameters (#5.3.2.3.7).

#2.5.3 Epoch Number shall range from 0 to 7, and shall be directly interpreted as the number of epochs used.

#2.5.4 If Epoch Number is N, then the first N words (see table 1) of the Epoch Specification Matrix shall be used, and the others shall be ignored.

#2.5.5 If the Epoch Number is zero, only the "Trigger Point" (#2.6) shall be sampled.

#2.5.5.1 If only the Trigger Point is sampled, the word "sweep" will refer to the data from the Trigger Point.

#2.6 There will always be a point sampled referred to as the "Trigger Point".

#2.6.0.1 The time that the Trigger Point is sampled (#1.3.3.1) will be referred to as the "Trigger Time".

#2.6.0.2 The temporal relationship of Trigger Time to the epochs is determined by the parameter "Trigger Location" (#5.3.2.3.3) of the Immediate Parameters.

#2.6.1 The Trigger Point is not counted in any epoch. It occurs just before one of the seven epochs or after the seventh.

#2.6.2 All points and epochs before the Trigger Point are "pre-stimulus".

#2.6.2.1 In pre-stimulus epochs, a point precedes its associated inter-point interval.

#2.6.3 All points and epochs following the Trigger Point are "post-stimulus".

#2.6.3.1 In post-stimulus epochs, a point follows its associated inter-point interval.

#3.0 Modes of Operation

#3.0.1 The subsystem will operate in either of two mutually exclusive modes: Synchronous Mode; or Asynchronous Mode.

#3.0.2 The selection of mode will be via the Immediate Parameters (#5.3.2.3.2).

#3.1 Synchronous Mode

#3.1.0.1 The Eclipse is the source of inter-sweep timing in Synchronous

Mode.

#3.1.1 A sweep is initiated by a "P" pulse from the Eclipse. (see #6.0)

#3.1.1.1 The first point of the sweep shall be sampled within 10.0 microseconds of the "P" pulse.

#3.1.1.2 The jitter and drift in the interval between the "P" pulse and the sampling of the first point of the sweep shall not exceed 0.50 microseconds.

#3.1.2 The subsystem can optionally deliver one or two simultaneous Output Trigger (#1.5.1) pulses associated with the sweep at Trigger Time (#2.6.0.1).

#3.1.2.1 The occurrence of each Output Trigger pulse is determined by a bit in the Immediate Parameters (#5.3.2.3.1).

#3.1.2.2 The difference between delivery of either of the Output Trigger pulses and Trigger Time (#2.6.0.1) shall not exceed 0.050 microseconds.

#3.1.2.3.1 If there are any data sampled following Trigger Time in a sweep, then the interval between Trigger Time and the the time the first point of the following epoch is sampled shall be the same as the point intervals within the following epoch, with no greater error (#2.3.3). (Note that the fact that Trigger Time occurs before an epoch does not require that any data be sampled for that epoch. This will depend on Epoch Number (#5.3.2.3.7)).

#3.1.2.3.2 If there are any data sampled preceding Trigger Time in a sweep, then the interval between the Trigger Point and the last point of the preceding epoch shall be an interval equal to the intervals of the preceeding epoch, with no greater error (#2.3.3).

#3.2 Asynchronous Mode

#3.2.0.1 The source of inter-sweep timing is external (#12.4) in Asynchronous Mode.

#3.2.1 A "P" pulse (#6.0) from the Eclipse initiates a "Pre-stimulus Period".

#3.2.1.0.1 The Pre-stimulus Period continues indefinitely until an External Trigger is detected (#12.4.2.3), at which time the Pre-stimulus Period is immediately terminated, and the Trigger Point is sampled. (#3.2.2.6, #3.2.2.8)

#3.2.1.0.2 During the Pre-stimulus Period, the subsystem may be either sampling pre-stimulus data, or idling.

#3.2.1.0.3 Whether or not there is pre-stimulus sampling is determined by selection of the Trigger Location (#5.3.2.3.3) (despite the fact that there is no Output Trigger delivered by the subsystem) in the

Immediate Parameters. If Trigger Time occurs before the first epoch (Trigger Location = 0), there is no pre-stimulus sampling. If Trigger Time occurs before the second sampling epoch (Trigger Location = 1), there is pre-stimulus sampling (even though there may or may not be post-stimulus sampling, depending on Epoch Number, #5.3.2.3.7). There are no other possibilities.

#3.2.1.0.3.1 In Asynchronous mode, a value of Trigger Location other than 0 or 1 will set the "Illegal Parameter" bit of Subsystem Status 1 (#8.2.9.4).

#3.2.1.1 This section (#3.2.1.1 and sub-sections) deals with the case where the subsystem samples pre-stimulus data during the Pre-stimulus Period.

#3.2.1.1.1 Pre-stimulus data are loaded into a "ring buffer" in the Eclipse memory. Each point is loaded into the Eclipse memory immediately after it is sampled.

#3.2.1.1.2 The length of the pre-stimulus ring buffer area exceeds the total number of pre-stimulus values (for all channels) by the number of channels per point. In other words, the ring buffer area has room for the number of points one greater than the number of pre-stimulus points in the pre-stimulus epoch. (see table 5)

#3.2.1.1.3 The first pre-stimulus point is sampled immediately (within 10.0 microseconds) upon receipt of the "P" pulse from the Eclipse and is loaded into the lowest address(es) of the ring buffer. Subsequent points are loaded into sequentially increasing addresses.

#3.2.1.1.4 When the ring buffer is full, the next point overwrites the first point sampled at the beginning of the ring buffer. Subsequent points are stored in sequential locations as before.

#3.2.1.1.5 A 13 bit register keeps track of the location of the most recent point delivered to the ring buffer. This register is referred to as "Pre-stimulus Pointer" (#11.1.3).

#3.2.1.1.5.1 Pre-stimulus Pointer is set to zero by the "C" pulse.

#3.2.1.1.5.2 Pre-stimulus Pointer is set to zero by the "P" pulse.

#3.2.1.1.5.3 Pre-stimulus Pointer is updated immediately following completion of delivery of the corresponding point to the pre-stimulus buffer in the Eclipse memory.

#3.2.1.1.5.4 If the point just transfered to Eclipse memory was stored in the lowest address of the ring buffer, Pre-stimulus pointer is set to one. If the point was stored elsewhere, Pre-stimulus Pointer is incremented by one.

#3.2.1.1.5.5 The final contents of this register are delivered to the 13 low order bits of a specified location in Header at the appropriate

time (#3.3.1, #9.3.2.1, #11.0).

#3.2.1.1.6 A bit in the Subsystem Status 1 (#8.2.6) is set to one when pre-stimulus sampling is initiated by the "P" pulse. This bit is set to zero when the number of pre-stimulus points required (equal to the Epoch Interval Count for the first epoch) has been stored in the ring buffer. This bit is referred to the "Incomplete Pre-stimulus Data" bit.

#3.2.1.1.7 The relationship between the last sample time (#1.3.3.1) of the pre-stimulus epoch and the Trigger Time (#2.6.0.1) will be kept track of by the subsystem and reported in the Header as follows (subsections of #3.2.1.1.7):

#3.2.1.1.7.1 At each pre-stimulus sample time, a 16 bit register referred to as "Pre-stimulus Skew" (#11.1.4) is set to zero.

#3.2.1.1.7.2 Subsequently, Pre-stimulus Skew is incremented at intervals equal to 1/8 of Base Sample Interval until the next pre-stimulus sample time (#3.2.1.1.7.1). (The unit of Pre-stimulus Skew measurement will therefore be 1/8 of the Base Sample Interval.)

#3.2.1.1.7.3 At each pre-stimulus sample time, a bit referred to as "Point Not Stored" (#8.2.11) in the Subsystem Status 1 (#8.1.1) register will be set to one.

#3.2.1.1.7.4 Point Not Stored will be cleared at the same time that Pre-stimulus Pointer is updated (#3.2.1.1.5.3).

#3.2.1.1.7.5 After the appropriate time after the External Trigger is detected (#3.2.2.3) no changes in Pre-stimulus Skew or Point Not Stored are allowed until a "C" or "P" pulse is received or there is loss of power.

#3.2.1.1.7.6 The "C" pulse clears Point Not Stored and Pre-stimulus Skew.

#3.2.1.1.7.7 The "P" pulse clears Point Not Stored and Pre-stimulus Skew.

#3.2.1.1.7.8 The "S" pulse alters neither Point Not Stored nor Pre-stimulus Skew.

#3.2.1.2 This section (#3.2.1.2 and subsections) deals with the case in which the subsystem is idling (not sampling pre-stimulus data) during the Pre-stimulus Period.

#3.2.1.2.1 No space in the Eclipse memory is provided for pre-stimulus data. The Trigger Point immediately follows the header (#9.3.2).

#3.2.2 This section (#3.2.2 and subsections) deals with detection of the External Trigger in Asynchronous Mode whether or not Pre-stimulus data are being sampled.

#3.2.2.1 Immediately upon detection of an External Trigger (#12.4.2.3) during the Pre-stimulus Period, the Trigger Point is sampled and

the post-stimulus period begins (#3.2.2.6, #3.2.2.8).

#3.2.2.2 Pre-stimulus sampling (if taking place) is aborted.

#3.2.2.3 Further modificaton of Pre-stimulus skew (#3.2.1.1.7.1) and Point Not Stored (#3.2.1.1.7.3) is prevented for the rest of the sweep (#3.2.1.1.7.5).

#3.2.2.4 The subsystem clock is immediately reset to assure synchrony between the External Trigger and the post-stimulus data.

#3.2.2.5 Trigger Time occurs (the Trigger Point is sampled, #2.6.0.1) immediately. This point is not counted in any epoch.

#3.2.2.6 The delay between the External Trigger detection (#12.4.2.3) and Trigger Time shall not exceed 0.50 microseconds.

#3.2.2.7 The delay between External Trigger detection and Trigger Time shall not differ by more than 0.050 microseconds between states where: (a) pre-stimulus data are sampled during the pre-stimulus period; and (b) the subsystem idles during the pre-stimulus period.

#3.2.2.8 The jitter in the delay between the External Trigger detection and Trigger Time shall not exceed 0.050 microseconds.

#3.2.2.9 The interval between Trigger Time and the sample time of the first post-stimulus epoch (when present) shall be the same as the inter-point intervals in the first post-stimulus epoch, with no greater error (#2.3.3).

#3.3 End of Sweep

#3.3.0.1 Section #3.3 and its subsections apply to both Synchronous and Asynchronous Modes.

#3.3.1 Within 1.0 microseconds after the last point of the sweep is sampled and delivered to the Eclipse memory, bits 0-1 of Subsystem Status 1 shall be set to octal 3, and transfer of header information appropriate to the selected mode (#9.3.1.1, #9.3.2.1, #11.0) shall be initiated.

#3.3.1.1 The header information shall be delivered by the subsystem to the Eclipse memory as fast as the Eclipse can accept it.

#3.3.2 Within 1.0 microseconds after delivery of the header to the Eclipse is completed, the busy flag shall be cleared and the done flag shall be set in the Eclipse-subsystem interface (#1.1.2.2).

#3.3.3 If Sweep Interrupt Selection (#5.3.2.3.6) of the Immediate Parameters is one, a program interrupt shall be requested.

#4.0 External Trigger Function

#4.0.1 External Trigger Specifications are discussed in section #12.4.

#4.1 The subsystem will be sensitive to External Triggers in both Asynchronous Mode and Synchronous Mode although such External Triggers are legal only in Asynchronous Mode.

#4.2 In Subsystem Status 1 (#8.1.1) there will be one bit to record the detection (#12.4.2.3) of External Triggers. This bit will be referred to as the "External Trigger Bit" (#8.2.12).

#4.2.1 The External Trigger Bit will be set by the occurance of an External Trigger (#12.4.2.3).

#4.2.2 The External Trigger Bit shall be cleared on power up.

#4.2.3 The External Trigger Bit shall be cleared when an event occurs as a consequence of External Trigger detection that is appropriate to the context in which the External Trigger was detected. The possible events are as follows:
a - the External Trigger causes Trigger Time in Asynchronous Mode (#3.2.2 and possibly #8.2.6);
b - the External Trigger occurs between sweeps (#4.2.6.3) in either mode (#8.2.5);
c - the External Trigger is a Post-stimulus Trigger in Asynchronous Mode (#8.2.7;
d - the External Trigger occurs in Synchronous Mode (#8.2.10).

#4.2.4 The External Trigger Bit will never be set for more than 0.50 microseconds during the processing of a sweep (after the "P" pulse has been delivered, but before the last point of the sweep is sampled (#1.3.3.1)). If the appropriate event listed in #4.2.3 has already occured for the current sweep, the External Trigger Bit shall be immediately cleared, and the information concerning the additional External Trigger shall be lost.

#4.2.5 An External Trigger that occurs while External Trigger Bit is set will be lost.

#4.2.6 The External Trigger Bit shall not be cleared between sweeps except by the "C" pulse (#6.1) or by power up.

#4.2.6.1 The phrase "between sweeps" shall refer to the time after the last point of a sweep is sampled (#1.3.3.1) and before the next "P" pulse is delivered.

#4.2.6.2 In (b) of #4.2.3, the External Trigger Bit is cleared when the next "P" pulse is delivered.

#4.2.6.3 In (d) of #4.2.3, when the illegal trigger occurs between sweeps (#4.2.6.1), the External Trigger Bit is cleared when the next "P" pulse is delivered.

#4.2.7 The External Trigger Bit is cleared by the "C" pulse (#6.1).

#5.0 Parameters

#5.0.1 The effects of parameter selection are illustrated in tables 4 and 5.

#5.1.1 The Universal and Immediate Parameters are retained by the subsystem until: power is lost; The Eclipse modifies the particular parameters, or a "C" pulse is delivered to the subsystem.

#5.1.2 If power is lost, and on initial power up, the "Power Up" bit of Subsystem Status 1 is set.

#5.1.2.1 The Power Up bit is cleared by the "C" pulse.

#5.1.2.2 The Power Up bit is cleared by the "S" pulse.

#5.1.2.3 The Power Up bit is not altered by the "P" pulse.

#5.2 Universal Parameters

#5.2.0.1 Table 1 shows the bit structure of the Universal Parameters.

#5.2.0.2 The Universal Parameters are delivered from the Eclipse memory to the subsystem via the data channel.

#5.2.1 The Universal Parameters are set into the subsystem by the Eclipse by the following sequence of events (subsections of #5.2.1).

#5.2.1.1 The Universal Parameters are set up in the Eclipse memory in a contiguous array by the application software.

#5.2.1.2 The low order 15 bits of an Eclipse accumulator is loaded with the address of the first word of this array by the application software. The 16 bit word in the accumulator is called the "Parameter Address Word", and is considered an Immediate Parameter.

#5.2.1.2.1 To transfer the Universal Parameters from Eclipse memory to the subsystem, bit 0 of the Parameter Address Word must be zero.

#5.2.1.3 The application software delivers a DOAS instruction to initiate the transfer of the Universal Parameters.

#5.2.1.4 In the Eclipse-subsystem interface the busy flag is set, the done flag is cleared, and a data channel transfer of the Universal Parameters from the Eclipse memory to the subsystem is initiated.

#5.2.1.4.1 The rate of this transfer shall be limited only by the Eclipse. The subsystem shall be able to receive the Universal Parameters at a rate greater than the rate at which the Eclipse can deliver.

#5.2.1.5 When transfer is complete, the done flag is set, and the busy flag is cleared in the Eclipse-subsystem interface.

#5.2.1.5.1 If the "Parameter Interrupt Selection" bit (#5.3.2.3.5) of the Immediate Parameters is set, an interrupt will be requested.

#5.2.1.5.2 At the same time the done flag is set, bits 0-1 of Subsystem Status 1 (#8.1.1) shall be set to octal 1 (#8.2.13).

#5.2.2 The following (subsections of #5.2.2) is a list of the Universal Parameters.

#5.2.2.1 Base Sample Interval (16 bits): This is the sample interval per channel in the fastest of the seven epochs. It has a range of 10 to 65535 microseconds.

#5.2.2.2 Epoch Specification Matrix (7 16 bit words): Each of the seven epochs requires two values for its specification:

#5.2.2.2.1 Sample Ratio Exponent (4 bit) is the base two logarithm of the number that multiplies the Base Sample Interval to get the sample interval for the epoch. It ranges from 0 to 12 [sic].

#5.2.2.2.1.1 If Sample Ratio Exponent for any epoch (irrespective of the value of Epoch Number, #5.3.2.3.7) is not in the range 0 to 12, Illegal Parameter (#8.2.9.1) of Subsystem Status 1 is set.

#5.2.2.2.2 Epoch Interval Count (12 bit) determines the number of intervals per channel for the epoch. It ranges from 0 to 4095 (but see #2.4.2).

#5.2.2.3 Channel Specification (8 bits): One bit is set for each channel to be digitized at each point. Within a point, the lowest channel is transfered to the lowest address in the Eclipse memory.

#5.2.2.3.1 The channel number (0 - 7) corresponds to the bit number in Channel Specification. Thus, if channel 0 is to be used, bit 0 is set, etc.

#5.2.2.4 Header Word Number (8 bits): The number of words allocated for header information. There will be a minimum number required by the A/D subsystem depending on mode (#9.3.1, #9.3.2, #11.0)

#5.2.2.5 Fire Parameter (12 bits): Specifies the External Trigger detection voltage level (see #12.4).

#5.2.2.6 Arm Parameter (12 bits): Specifies the External Trigger arm voltage level (see #12.4).

#5.3 Immediate Parameters

#5.3.0.1 The bit structure of the Immediate Parameters is shown in table 2.

#5.3.0.2 The Immediate Parameters are transmitted from the Eclipse via

accumulator transfer.

#5.3.0.2.1 In Asynchronous Mode, this should be done, if necessary, immediately after servicing the interrupt for the previous sweep.

#5.3.0.2.2 In Synchronous Mode, this may be done any time after interrupt service but before the next sweep is initiated.

#5.3.1 The Immediate Parameters are transfered from the Eclipse to the subsystem by accumulator transfer utilizing the DOA, DOB and DOC instructions.

#5.3.2 There are three words in the Immediate Parameters: the Parameter Address Word, the Data Address Word, and the Control Word. This section (#5.3.2 and its subsections) details the Immediate Parameters.

#5.3.2.1 Parameter Address Word: The Parameter Address Word contains, right adjusted, the 15 bit logical address of the first word of the Universal Parameters in the Eclipse memory ready for transfer to the subsystem (#5.2.1) or the first word of the Eclipse memory to receive the Diagnostic Register Readout (see #7.0). Bit 0 of the Parameter Address words selects as follows: 0 - transfer Universal Parameters from Eclipse to subsystem; 1 - transfer Diagnostic Registers from subsystem to Eclipse.

#5.3.2.1.0.1 The DOA instruction transfers all 16 bits of the Parameter Address word from the specified accumulator to the subsystem.

#5.3.2.2 Data Address Word: The Data Address Word contains, right adjusted, the 15 bit "First Buffer Location", which is the logical address of the first word of the Header, which is the beginning of the storage area for the sweep. In conjunction with other parameters, it determines where all of the data associated with a single sweep are to be stored. (#9.3)

#5.3.2.2.0.1 The DOB instruction transfers Data Address word from the least significant (right) 15 bits of the specified accumulator of the Eclipse to the subsystem.

#5.3.2.3 Control Word: The Control Word contains numerous parameters of a few bits each. These are detailed in the following subsections (of #5.3.2.3).

#5.3.2.3.0.1 The DOC instruction transfers all 16 bits of the Control Word from the specified Eclipse accumulator to the subsystem.

#5.3.2.3.0.2 When the DOC instruction transfers the Control Word from an Eclipse accumulator to the subsystem, the bits of the Control Word register within the subsystem that are not to be changed by the new value shall not be even transciently altered.

#5.3.2.3.0.3 The arrangement of the bits in the control word shall be as specified in table 2.

#5.3.2.3.1 Output Trigger Selection (2 bits): In Synchronous Mode, each bit, if set, allows delivery of one of the two Output Triggers (referred to as "Output Trigger A" and "Output Trigger B") at the appropriate time. No Output Triggers are delivered in Asynchronous mode, and these two bits should be zero (#3.1.2).

#5.3.2.3.1.1 If either or both of the Output Trigger Selection bits is one, and Mode Selection (#5.3.2.3.2) is one, the Illegal Parameter bit (#8.2.9) of Subsystem Status 1 (#8.1.1) shall be set.

#5.3.2.3.2 Mode Selection (1 bit): Select Synchronous (0), or Asynchronous Mode (1). (#3.0)

#5.3.2.3.3 Trigger Location (3 bits): This is the location of Trigger Time (#2.6.0.1) in each sweep. Trigger Time can occur at the beginning of any of the seven epochs, or at the end of the last epoch (#2.6.1). There are therefore eight possibilities. The range of this parameter is 0 to 7. Trigger Location is important in both Synchronous (#3.1) and Asynchronous (#3.2, esp. #3.2.1.0.3) Modes.

#5.3.2.3.3.1 Trigger Location may not exceed Epoch Number (#5.3.2.3.7) by more than one.

#5.3.2.3.3.2 If Trigger Location exceeds Epoch Number by more than one, Illegal Parameter (#8.2.9) of Subsystem Status 1 shall be set.

#5.3.2.3.3.3 If Epoch Number is zero, Trigger Location is ignored since only the Trigger Point is sampled (#2.5.5).

#5.3.2.3.3.4 For all Trigger Location values (0 to 7), increasing value shall correspond to later trigger times within the sweep.

#5.3.2.3.4 Data Channel Map Selector (2 bits): The Memory Management and Protection Unit (MMPU) of the Eclipse S140 can hold four data channel maps which specify the relationship between the logical addresses seen by an I/O device and physical addresses in Eclipse memory. These two bits will select among these maps as follows: 00 - MAP A; 01 - MAP B; 10 - MAP C; 11 - MAP D.

#5.3.2.3.5 Parameter Interrupt Selection (1 bit)· If this bit is set, an interrupt is delivered when the done flag is set after delivery of the Universal Parameters (#5.2.1.5.1), or transfer of the Diagnostic Registers. (see #7.2.5.1)

#5.3.2.3.6 Sweep Interrupt Selection (1 bit): If this bit is set, an interrupt is delivered when the done flag is set after processing a sweep (#3.3.3).

#5.3.2.3.7 Epoch Number (3 bits): Specifies the number of epochs to be used. The range is 0 to 7 (#2.5.1). If 0 is specified, only the Trigger Point is sampled (#2.6).

#5.3.2.3.8 Output Trigger Polarity (2 bits): Each bit selects the polarity

of the of the Output Trigger Pulses (see #5.3.2.3.1 and table 2).

#5.3.2.3.8.1 For each Output Trigger Polarity bit, 0 shall indicate a positive pulse, and 1 shall indicate a negative pulse (see #12.5).

#5.3.2.3.8.2 Output Trigger Polarity shall be ignored in Asynchronous mode.

#6.0 Control Pulses

#6.0.1 Standard Eclipse I/O procedures allow delivery of three pulses to the subsystem. These are: "C" (clear); "S" (start); and "P" (special).

#6.0.2 Specific functions of these three pulses are given throughout this specification.

#6.1 The "C" pulse will stop any A/D conversion that may be in progress, and immediately terminate modification of Eclipse memory until further commands are delivered.

#6.1.1 The "C" pulse clears the busy and done flags of the Eclipse-subsystem interface.

#6.1.2 The "C" pulse will clear Subsystem Status 1 (#8.1.1) and Subsystem Status 2 (#8.1.5.2).

#6.1.3 The "C" pulse shall not alter subsystem parameter registers.

#6.2 The "S" pulse will initiate transfer of the Universal Parameters from the Eclipse memory to the subsystem (#5.2.1), or transfer of the Diagnostic Registers from the subsystem to the Eclipse memory (#7.2).

#6.2.1 The "S" pulse clears the done flag and sets the busy flag of the Eclipse-subsystem interface.

#6.2.2 When Universal Parameters are transferred using the "S" pulse (#5.2.1), after the transfer is complete, a parameter check will be run on all parameters, and the Illegal Parameter bit (#8.2.9) of Subsystem Status 1 (#8.1.1) will be cleared or set, depending on the result.

#6.3 The "P" pulse will initiate processing of a sweep. (see #3.0 and #10.0)

#6.3.1 The "P" pulse clears the done flag and sets the busy flag of the Eclipse-subsystem interface.

#6.3.2 Immediately after the delivery of a "P" pulse, a parameter check will be run and the Illegal Parameter bit (#8.2.9) of Subsystem Status 1 (#8.1.1) will be cleared or set, depending on the result. If the Illegal Parameter bit is set, the sweep processing will not begin. Rather, the busy flag will be cleared, and the done flag will be set in the Eclipse-subsystem interface (#1.1.2).

#7.0 Diagnostic Register Readout

#7.1 For diagnostic purposes, a procedure shall be provided which transfers many of the registers of the subsystem to the Eclipse memory via the data channel.

#7.2 The subsystem registers are transfered from the subsystem to the Eclipse memory by the following procedure (subsections of #7.2).

#7.2.1.1 The application software loads bits 1 - 15 of an Eclipse accumulator with the address of the first memory word to receive the data.

#7.2.1.2 The application software sets bit 0 of this accumulator to one.

#7.2.3 The application software delivers a DOAS instruction to initiate the transfer.

#7.2.4 The busy flag of the Eclipse-subsystem interface is set, the done flag is cleared, and a data channel transfer of the subsystem registers is initiated.

#7.2.4.1 The rate of this transfer shall be limited only by the Eclipse. The subsystem shall be able to deliver the data at a rate greater than the rate at which the Eclipse can receive.

#7.2.5 When transfer is complete, the done flag is set, and the busy flag is cleared in the Eclipse-subsystem interface.

#7.2.5.1 If the "Parameter Interrupt Selection" bit (#5.3.2.3.5) of the Immediate Parameters is set, an interrupt shall be requested.

#7.2.5.2 At the same time the done flag is set, bits 0-1 of Subsystem Status 1 (#8.1.1) shall be set to octal 2 (#8.2.13).

#7.2.6 The information delivered to the Eclipse memory will be in the following sequence (with explanations in the indicated paragraphs):

low memory	Universal Parameters	#7.2.6.1
.	Immediate Parameters	#7.2.6.2
.	Header Information	#7.2.6.3
.	Conversion Registers	#7.2.6.4
high memory	Other Information	#7.2.6.5

#7.2.6.1 The Universal Parameters will appear is the same format used in their initial set-up, as specified in table 1.

#7.2.6.2 The Immediate Parameters will appear in the following sequence:

Parameter Address Word	#5.3.2.1 & table 2
Data Address Word	#5.3.2.2 & table 2
Control Word	#5.3.2.3 & table 2

#7.2.6.3 The header information will appear in the sequence given in section #11.0.

#7.2.6.3.1 Pre-stimulus Pointer (#11.1.3) and Pre-stimulus Skew (#11.1.4) will be delivered in the Diagnostic Parameter Readout irrespective of mode.

#7.2.6.3.2 Software-Supplied Information (#11.1.5) shall not be included in the diagnostic readout, nor shall space be left for it.

#7.2.6.4 For the purpose of discussion (without prejudicing the final design) it is assumed that within the subsystem, there will be one register for each channel to hold A/D conversion results or intermediate results. If these are used in the design, they will appear in the Diagnostic Register Readout in order of channel number.

#7.2.6.4.1 If there is only one A/D conversion register, it shall be output in the Diagnostic Register Readout.

#7.2.6.5 Other information that would be of value to shall be included in the Diagnostic Register Readout.

#8.0 Subsystem Status Words

#8.1.1 The A/D subsystem will check for various conditions. Each condition will set one or more bits in a register referred to as "Subsystem Status 1" to 1.

#8.1.2 Subsystem Status 1 is transmitted to the designated word in Header area of the Eclipse memory at the appropriate time (#3.3.1).

#8.1.3 Subsystem Status 1 may be transfered at any time from the subsystem to an Eclipse accumulator with a DIA instruction.

#8.1.3.1 The DIA status transfer can be executed at any time without affecting any other operations.

#8.1.4 Most, but not all of the bits in Subsystem Status 1 are error conditions.

#8.1.5 Any additional conditions that may be important to prevent transmission of faulty data without warning shall be identified and implemented.

#8.1.5.1 These additional error conditions will be reported in unused bits of Subsystem Status 1.

#8.1.5.2 If there are more conditions than can be accommodated in the unused portion of Subsystem Status 1, an additional 16 bit register, to be referred to as "Subsystem Status 2" shall be used.

#8.1.5.2.1 This additional 16 bit register will be transmitted to the Header immediately following Subsystem Status 1 (#9.3.1.1, #9.3.2.1,

#11.0).

#8.1.5.2.2 Other data transmitted from the subsystem to the Eclipse memory will by moved up one word to provide the necessary space.

#8.1.5.2.3 It will be possible to transfer Subsystem Status 2 from the subsystem to an Eclipse accumulator with a DIB instruction at any time.

#8.1.5.2.3.1 The DIB status transfer shall be able to be executed at any time without affecting any other operations.

#8.2 The following (subsections of #8.2) is a list of conditions, with the bit location in Subsystem Status 1 given in parentheses. Summary information appears in table 3.

#8.2.0.1 The bits are numbered 0 to 15. Zero (0) is the most significant (left most) bit.

#8.2.1 ADC Not Ready (bit 15): On the input sample-and-hold amplifiers, the hold state is called for before a previous conversion and settling sequence is completed. (see #1.8)

#8.2.2 Subsystem Overrun (bit 14): Conversion is initiated before data from the previous conversion are copied from subsystem registers by the data channel. (see #1.8)

#8.2.3 Inappropriate Parameter Modification (bit 13): The Eclipse tried to modify subsystem parameters after delivery of the "P" pulse, but before the done flag of the Eclipse-subsystem interface is set (#3.1.1, #3.2.1, #3.3.2, #10.0).

#8.2.3.1 If Inappropriate Parameter Modification is set, it should be cleared with the "C" pulse by the application software (#10.1.11.1).

#8.2.3.2 Since Inappropriate Parameter Modification can be set between the time Subsystem Status 1 is normally delivered to the Eclipse memory (#3.3.1) and the time the done flag is set (#3.3.2), the error may have occurred in the sweep before the one in which it is reported.

#8.2.4 False Start (bit 12): The Eclipse delivers a "P" pulse to the subsystem after another "P" pulse has been delivered, but before the done flag of the Eclipse-subsystem interface is set (#3.1.1, #3.2.1, #3.3.2, #10.0).

#8.2.4.1 If False Start is set, it should be cleared with the "C" pulse by the application software (#10.1.11.1).

#8.2.4.2 Since False Start can be set between the time Subsystem Status 1 is normally delivered to the Eclipse memory (#3.3.1) and the time the done flag is set (#3.3.2), the error may have occured in the sweep before the one in which the error is reported.

#8.2.5 Trigger Between Sweeps (bit 11): In either mode, at least one External Trigger has been detected (#12.4.2.3) between sweeps (#4.2.6.1). The trigger is otherwise ignored.

#8.2.5.1 Trigger Between Sweeps is set, if appropriate, when the next "P" pulse is delivered (#4.2.6.2).

#8.2.6 Incomplete Pre-stimulus Data (bit 10): In Asynchronous Mode, an External Trigger is detected (#3.2.2, #4.0, #12.4.2.3) after Pre-stimulus sampling is initiated, but before the specified amount of Pre-stimulus data is gathered. Post-stimulus sampling is immediately initiated as usual. (#3.2.1.1.6)

#8.2.7 Post-stimulus Trigger (bit 9): In Asynchronous Mode, at least one External Trigger is detected (#3.2.2, #4.0, #12.4.2.3) between the time the first External Trigger of the sweep is detected (#3.2.2) and the time the last point of the sweep was sampled (#1.3.3.1). The External Trigger is ignored.

#8.2.8 Power Up (bit 8): Power has been low since the last delivery of a "C" or "S" pulse to the subsystem (#5.1.2).

#8.2.9 Illegal Parameter (bit 7): Inconsistant or illegal parameters have been transmitted. The specific situations which set this bit are as follows (subsections of #8.2.9):

#8.2.9.0.1 The times at which Illegal Parameter can actually be set are immediately after an "S" pulse (#6.2.2) or immediately after a "P" pulse (#6.3.2).

#8.2.9.1 One or more of the seven values of Sample Ratio Exponent (#5.2.2.2.1) is out of the range 0 to 12.

#8.2.9.2 Header Word Number (#5.2.2.4) is less than the minimum number required by the subsystem for the selected mode.

#8.2.9.3 One or both of the Output Trigger Selection bits (#5.3.2.3.1) is set in Asynchronous Mode (#5.3.2.3.2).

#8.2.9.4 Asynchronous Mode is selected (#5.3.2.3.2) and Trigger Location (#5.3.2.3.3) has a value that is neither 0 nor 1.

#8.2.9.5 The Base Sample Interval (#5.2.2.1) is less than 10 microseconds.

#8.2.9.6 The two External Trigger Parameters are the same (#12.4.1.7.1).

#8.2.9.7 Trigger Location exceeds Epoch Number by more than one (#5.3.2.3.3.2).

#8.2.10 External Trigger In Synchronous Mode (bit 6): Either an External Trigger was detected after Synchronous Mode was selected, or Synchronous Mode was selected after an External Trigger was detected.

#8.2.10.1 If the trigger is detected (#12.4.2.3) between sweeps (#4.2.6.1), External Trigger in Synchronous Mode is set when the next "P" pulse is delivered.

#8.2.10.2 If the trigger is detected (#12.4.2.3) after the "P" pulse is delivered (#3.1.1), but before the last point is sampled (#1.3.3.1), External Trigger in Synchronous Mode is set immediately.

#8.2.11 Point Not Stored (bit 5): The point sampled at the last pre-stimulus sample time is not yet stored in Eclipse memory despite the fact that Pre-stimulus Skew is measuring from this last sample time (#3.2.1.1.7).

#8.2.12 External Trigger Bit (bit 4): Records occurance of an External Trigger pending further action (#4.0).

#8.2.13 Transmission Complete (bits 0-1): The done flag of the Eclipse-subsystem interface was set for the reason indicated by the configuration of the two bits shown (octal):
0 - illegal;
1 - Universal Parameter transmission complete (#5.2.1.5.2);
2 - Diagnostic Register transmission complete (#7.2.5.2);
3 - Sweep complete (#3.3.2.1).

#8.3.1 The "C" pulse unconditionally clears all bits of Subsystem Status 1.

#8.3.2.1 If Diagnostic Registers are being transmitted (#7.2), the "S" pulse does not alter Subsystem Status 1.

#8.3.2.2 If Universal Parameters are being transmitted (#5.2.1), Subsystem Status 1 is modified as follows:
a - all bits except 4, 7, 12, and 13 are unconditionally cleared;
b - bits 4, 12, and 13 are not modified;
c - bit 7 may be cleared or set as indicated in #6.2.2.

#8.3.3.1 Except in the case of a False Start (#8.2.4), the "P" pulse effects Subsystem Status 1 as follows:
a - bits 0, 1, 4, 5, 9, 10, 14, and 15 are unconditionally cleared;
b - bit 6 is cleared or set as indicated in #8.2.10;
c - bit 7 is cleared or set as indicated in #6.3.2;
d - bit 11 is cleared or set as indicated in #8.2.5;
e - bits 8, 12, and 13 are unaffected.

#8.3.3.2 In the case of a False Start (#8.2.4), bit 12 of Subsystem Status 1 is set, and no other bits are affected.

#9.0 Eclipse Memory Utilization

#9.0.1 The subsystem will have access to up to 32,768 16 bit words of Eclipse memory as specified by the selected data channel map (#5.3.2.3.4). These words have logical addresses 0 to up to

32,767.

#9.0.2 Data channel access to Eclipse memory is used by the subsystem for three purposes: to transfer the Universal Parameters from the Eclipse memory to the subsystem; to transfer digitized sweep data and related status information from the subsystem to the Eclipse memory; and to transfer parameters and other information from the subsystem to the Eclipse memory for diagnostic purposes.

#9.0.3 When the subsystem is storing sweeps in Eclipse memory, memory utilization depends on whether Synchronous Mode or Asynchronous Mode is selected.

#9.0.4 In the following discussion (subsections of #9.0) it will be assumed that Subsystem Status 2 (#8.1.5.2) is implemented. If it is not implemented in the final design, no space is to be left for it.

#9.0.5 Tables 4 and 5 illustrate aspects memory utilization.

#9.1 Universal Parameter Memory Utilization

#9.1.1 The location of the Universal Parameters in Eclipse memory relative to the address in the Parameter Address Word is shown in table 1.

#9.2 Diagnostic Readout Memory Utilization

#9.2.1 Memory utilization for the Diagnostic Readout is described in section #7.2.6.

#9.3 Sweep Storage

#9.3.0.1 In both Synchronous and Asynchronous Modes, the Eclipse memory is divided into four contiguous sections as follows:

low memory	Header
.	Pre-stimulus Data
.	Trigger Point
high memory	Post-stimulus Data

#9.3.0.2 The length of each of the four sections depends upon the parameters.

#9.3.0.3 Pre-stimulus Data or Post-stimulus Data may or may not be present for any particular choice of parameters.

#9.3.0.4 Header and Trigger Point are always present.

#9.3.0.5 In memory utilization for storage of digitized sweeps and related header information, there shall be no gaps except where specified.

#9.3.0.6 Where digitized data are stored in Eclipse memory, the data for a point (#1.3.3) are stored with increasing channel number

corresponding to increasing memory address. Where there are gaps in the channel number because some channels are not used, no gaps shall be left in memory for unused channels.

#9.3.0.7 The first word of the Header is always the location specified in the Data Address Word (#5.3.2.2).

#9.3.1 Sweep Storage -- Synchronous Mode

#9.3.1.0.1 Synchronous Mode memory utilization is illustrated in table 4.

#9.3.1.1 The Header shall be in the following sequence:

low memory	Subsystem Status 1
.	Subsystem Status 2
.	Software-Supplied Data 1
.	Software-Supplied Data 2
.	.
high memory	.

#9.3.1.2 The minimum number of words in the Header is 2.

#9.3.1.3 Any additional words in the Header as specified in the Header Word Number (#5.2.2.4) shall not be altered by the subsystem.

#9.3.1.4 The Points for Pre-stimulus Data, Trigger Point, and Post-stimulus Data are placed in memory following the Header in order of acquisition.

#9.3.2 Sweep Storage -- Asynchronous Mode

#9.3.2.0.1 Asynchronous Mode memory utilization is illustrated in table 5.

#9.3.2.1 The Header shall be in the following sequence:

low memory	Subsystem Status 1
.	Subsystem Status 2
.	Pre-stimulus Pointer
.	Pre-stimulus Skew
.	Software-Supplied Data 1
.	Software-Supplied Data 2
.	.
high memory	.

#9.3.2.2 The minimum number of words in the Header is 4.

#9.3.2.3 Any additional words in the Header as specified by the Header Word Number (#5.2.2.4) shall not be altered by the subsystem.

#9.3.2.4 In the pre-stimulus section, the points do not, in general, appear in the order of acquisition. Details of pre-stimulus memory utilization are described in section #3.2.1.1.

#9.3.2.4.1 The number of points in the pre-stimulus memory section is one

more than indicated for the pre-stimulus epoch (#3.2.1.1.2).

#9.3.2.5 In the Trigger Point and post-stimulus sections, points are placed in memory in the order of acquisition.

#10.0 Subsystem Operation

#10.0.1 This section (#10.0 and its subsections) describes the sequence of operations in a typical Eclipse control program.

#10.1.1 Load an accumulator with the Control Word and transmit it to the subsystem with a DOC instruction.

#10.1.1.1 A DOCC instruction may be used instead of a DOC instruction if it is desired to clear Subsystem Status 1 (#8.1.1). Note that any information recorded in Subsystem Status 1 will be lost.

#10.1.1.2 Note that if the accumulator transfer of the Control Word results in an illegal parameter combination, the Illegal Parameter bit (#8.2.9) will not be set until Universal Parameters are next transferred (#6.2.2) or the next sweep is initiated (#6.3.2).

#10.1.2 Set up Universal Parameters in a sequence of words in Eclipse memory.

#10.1.3 Load an Eclipse accumulator with the address of the first word of the Universal Parameters (the Parameter Address Word). Be sure bit 0 of this accumulator is zero.

#10.1.4 A DOAS command initiates transfer of all of these parameters to the subsystem via the data channel.

#10.1.5 When transfer is complete, the done flag is set, and optionally, an interrupt is delivered.

#10.1.6 Retrieve Subsystem Status 1 with a DIA instruction. Octal 040000 indicates complete transmission of Universal Parameters.

#10.1.6.1 Any result other than octal 040000 indicates some kind of problem (#8.2). Each problem may be dealt with differently, depending on the context.

#10.1.7 Load an accumulator with the Data Address Word and transmit it to the subsystem with a DOB instruction.

#10.1.8 A "P" pulse initiates action appropriate to the selected mode. This "P" pulse may be delivered alone (NIOP command) or in combination with the previous command (DOBP command).

#10.1.9 If Sweep Interrupt Selection (#5.3.2.3.6) was one, the Eclipse may then proceed with other activities until the done flag of the Eclipse-subsystem interface (#1.1.2.2) is set, and an interrupt is delivered.

#10.1.10 When the done flag is set, the status word is retrieved from the appropriate Eclipse memory location (#11.1.1).

#10.1.11 If the status indicates normal completion of a sweep, the Eclipse may compute new parameters and deliver them to the subsystem. Another "P" pulse may be delivered to initiate a new sweep.

#10.1.11.1 If bit 12 or 13 is set, a program error or a hardware malfunction is indicated. Besides any other action taken, a "C" pulse should be delivered to the subsystem to clear these bits so that additional occurrences might be detected. (see #8.2.3 and #8.2.4)

#10.1.11.2 Normally, interrupts should be enabled (#5.3.2.3.6), and usually, the only parameter modified between sweeps will be the Data Address Word (#5.3.2.2). This allows a multiple buffering environment in which a sweep is processed by the Eclipse while the next is being digitized by the subsystem.

#10.1.12 If the status word indicates an error, appropriate action is taken by the application software. Possibilities include proceeding normally as above, or aborting the program.

#10.1.13 At any time, delivery of a "C" pulse shall immediately stop A/D conversions and stop modifications of Eclipse memory.

#11.0 Header Word Sequence

#11.0.1 This section (#11.0 and its subsections) summarizes the header delivered to the Eclipse memory with each sweep. Pre-stimulus Pointer (#11.1.3) and Pre-stimulus Skew (#11.1.4) are used only in Asynchronous Mode (see #9.3.1.1 and #9.3.2.1).

#11.1.1 Subsystem Status 1: Status of the subsystem at the time of delivery (#8.1.1, table 3).

#11.1.2 Subsystem Status 2: This is an optional design feature to be used if there is more status information to transmit than there is room for in the previous word (#8.1.5.2).

#11.1.2.1 If Subsystem Status 2 is not used, space is not to be left for it in the header. All subsequent data are to be moved back.

#11.1.3 Pre-stimulus Pointer (13 low order bits): In Asynchronous Mode, provides information for sorting the pre-stimulus ring buffer (#3.2.1.1.5).

#11.1.4 Pre-stimulus Skew (16 bits): In Asynchronous Mode, indicates temporal relationship between the pre-stimulus data and the stimulus. (see #3.2.1.1.7.1)

#11.1.5 Software-Supplied Information: Optionally supplied by the application software. Number of words varies and is determined by Header Word Number (#5.2.2.4) of the Universal Parameters. The contents of these Eclipse memory locations shall not be modified

by the subsystem.

#12.0 General Performance Requirements

#12.1 Logical Performance

#12.1.1 The subsystem shall be designed so that its various functions, including receipt of information from the External Trigger or from the Eclipse, do not interfere with one another.

#12.1.2 The subsystem shall be designed utilizing internal clocked logic.

#12.1.2.1 Throughout this document, the concept of "simultaneity" shall be interpreted to mean "in the same phase of the same clock cycle".

#12.1.2.2 The number of logic clock cycles for the various operations shall be such that none of the timing tolerances indicated throughout this specification are exceeded.

#12.1.2.3 Throughout this document, the concept of "immediately following" shall be interpreted to mean "soon enough so that there is no uncertainty with regard to subsequent function".

#12.1.3 For each word that these specifications indicate should be transfered between the Eclipse memory and the subsystem, only one data channel cycle shall be consumed.

#12.1.3.1 Designs in which control information stored in the Eclipse memory must be transfered to the subsystem each time a word is to be digitized are specifically excluded.

#12.1.3.2 More generally, designs which require data channel usage in excess of that required by the logic of the specified design are excluded.

#12.2 Temperature Specifications

#12.2.1 The installed subsystem shall operate within all specifications in the evironmental temperature range 5° to 35° centigrade.

#12.2.2 The subsystem shall operate within all specifications after a warm up time not to exceed five minutes.

#12.3 A/D Input Specifications

#12.3.1 Each of the eight A/D inputs shall be single-ended referred to a common ground.

#12.3.2 The nominal input range shall be -10 to +10 volts.

#12.3.2.1 The ideal end point and zero transition points shall be -9.99512, 0.0000, and +9.99512 volts.

#12.3.2.2 The value of the least significant bit (LSB) shall be 0.00488

volts.

#12.3.2.3 Each channel shall be adjustable with no more that two potentiometers so that each of the 4095 transition voltages differs from the ideal value (assuming the transition voltages specified in #12.3.2.1 and perfect linearity) by less than ½LSB (0.00244 volts).

#12.3.2.3.1 Such adjustment shall not be necessary more often than once every six months to obtain the specified accuracy.

#12.3.2.3.2 Complete documentation of the calibration procedure shall be provided.

#12.3.3 Each A/D input shall be able to withstand any input within the range -30 to +30 volts for at least 24 hours without damage.

#12.3.4 Each A/D channel shall function within its specifications in the presence of common mode voltage (channel input to ground) of 250 volts DC or 250 volts RMS up to 60 Hz.

#12.3.4.1 Such common mode voltages shall produce no damage if applied for at least 24 hours.

#12.3.5 The input impedance of each A/D input shall be no less than 100 megohms resistance with no more than 100 picofarads capacitance.

#12.3.6 Each of the eight A/D channel inputs shall operate within all specifications for full range input signals ranging from DC to 10 kHz., with the possible exception of a constant temporal offset due to Aperture Delay and other sources.

#12.3.6.1 The total constant temporal offset referred to in the previous paragraph shall not exceed 20 nanoseconds.

#12.3.6.2 The jitter and drift in the total temporal offset referred to in the previous paragraph shall not exceed ±0.97 nanoseconds.

#12.3.6.3 Detailed performance characteristics for full scale and small signals ranging from DC to 100 kHz. shall be available prior to fabrication.

#12.4 External Trigger Specifications

#12.4.1 The detection of External Trigger shall be controlled by two voltage levels, the "Fire Level" and the "Arm Level". Collectively, the "Fire Level" and the "Arm Level" will be referred to as the "External Trigger Levels".

#12.4.1.1 Each of the External Trigger Levels will be controlled by a Universal Parameter. These parameters will be referred to as the "Fire Parameter" and the "Arm Parameter". Collectively, these two parameters will be referred to as the "External Trigger Parameters".

#12.4.1.2 Each of the External Trigger Parameters will be a 12 bit 2's complement number.

#12.4.1.3 The nominal range of the External Trigger Levels shall be -10 to +10 volts.

#12.4.1.4 Each External Trigger Level shall be monotonically determined by its corresponding External Trigger Parameter, with the most positive External Trigger Level resulting from the most positive External Trigger Parameter.

#12.4.1.5 Ideally, the most negative value (-4096) of an External Trigger Parameter shall result in an External Trigger Level of -10.00000 volts, a zero External Trigger Parameter shall result in an External Trigger Level of 0.00000 volts, and the most positive value (+4095) in an External Trigger Level of +9.99512 volts.

#12.4.1.6 The hardware for each of the External Trigger Levels shall be adjustable with no more than two potentiometers so that each of the 4096 External Trigger Levels differs from the ideal value (assuming the values specified in #12.4.1.5 and perfect linearity) by less than 0.00244 volts (½LSB).

#12.4.1.6.1 Such adjustment shall not be required more often that once every six months in order to obtain the specified accuracy.

#12.4.1.6.2 Complete documentation of the calibration procedure shall be provided.

#12.4.1.6.3 If any voltage measurements of points within the subsystem are required for calibration, the voltage measurement points shall be easily accessible.

#12.4.1.7 The Fire Parameter and the Arm Parameter are not to be set to the same value.

#12.4.1.7.1 If the Fire Parameter and the Arm Parameter are set to the same value, the Illegal Parameter bit (#8.2.9) of Subsystem Status 1 shall be set.

#12.4.2.1 Detection of an External Trigger (#4.2) shall occur if and only if the following sequence of events occurs:

a - Since power up, the last delivery of a "C" pulse, or the last detection of an External Trigger, the trigger external voltage is, equal to the Arm Level, or is on the side of the Arm Level farthest from the Fire Level.

b - Since (a) occured, the trigger external voltage becomes equal to the Fire Level, or is on the side of the Fire level farthest from the Arm level.

#12.4.2.2 For the purpose of the discussion in #12.4.2.1, a voltage shall be considered at or beyond a level if the condition is satisfied for

more than 50 nanoseconds.

#12.4.2.3 The time that the External Trigger is considered detected shall be within 50 nanoseconds of the time that event (b) of #12.4.2.1 occurs.

#12.5 Output Trigger Specifications

#12.5.1 Each Output Trigger shall be at ground ±0.250 volts in the absence of an Output Trigger.

#12.5.2 Each of the two output pulses shall be a "rectangular" pulse with no greater than 50 nanoseconds rise and fall times and 1.0±0.05 milliseconds duration.

#12.5.3 The polarity of each pulse shall be separately selectable by a bit in Output Trigger Polarity (#5.3.2.3.8) in the Immediate Parameters.

#12.5.4 The amplitude of each output pulse shall be ±5.0±0.1 volts.

#12.5.5 The output impedance of each Output Trigger shall be no more than 100 ohms.

#12.5.6 Each Output Trigger shall be able to withstand clamping at any voltage from -30 to +30 volts for 24 hours without damage.

#13.0 Subsystem Buffering

#13.0.1 This section (#13.0 and its subsections) outlines additions to the subsystem the inclusion of which shall depend upon cost-benefit considerations.

#13.0.2 The the additional cost of each of the two types of Subsystem Buffers outlined here (#13.1, #13.2), the additional cost of the enhancements indicated (#13.2.3, #13.2.4), as well as any other relevant modifications shall be considered.

#13.0.3 Subsystem Buffering will be only outlined here.

#13.0.4 The details of any modifications shall be carefully considered before inclusion.

#13.0.5 Inclusion of Subsystem Buffering will require modification of various parts of this specification. For example, it is likely that additional status information will be required to deal with additional problems that may arise.

#13.1 Word Buffering

#13.1.1 The subsystem may include a "first in first out" word buffer in front of the data channel.

#13.1.2 A suggested length for this buffer is 256 words.

#13.1.3 It is noted that 16 bit words are required because the Header information is 16 bit.

#13.1.4 It is also noted that delivery of information to the Eclipse memory is not always in order of increasing Eclipse memory addresses. There are two reasons for this. First, the operation of the Pre-stimulus ring buffer in Asynchronous Mode requires that a certain portion of the Eclipse memory be written in repeatedly. Second, the some of the header information, which is stored at the lowest Eclipse addresses, is the last to be delivered.

#13.2 Sweep Buffering

#13.2.1 Entire sweeps could be constructed in subsystem buffers and be transfered to the Eclipse memory when they are complete.

#13.2.2 In this case, data could be delivered to the Eclipse memory in order of increasing addresses except that certain locations in the header area of Eclipse memory would have to be left unaltered.

#13.2.3 Additionally, in Asynchronous Mode, it is possible to sort the data in the Pre-stimulus ring buffer into ascending order during the data transfer to Eclipse memory.

#13.2.4 It is also possible to avoid transmitting the extra point in the Prestimulus ring buffer (#3.2.1.1.2) to the Eclipse memory, so that in Eclipse memory, the length of the Pre-stimulus section will not dependent upon mode.

#13.2.5 Double Sweep Buffering would be required because the subsystem must not be unable to accept input for as long as it would take to transfer a sweep to the Eclipse memory.

#13.2.6 Each of the two Sweep Buffers must have a capacity of at least 4097 [sic] words.

TABLE 1: Arrangement of Universal Parameters in Eclipse Memory

The Universal Parameters in Eclipse Memory ready for data channel transfer to the subsystem are arranged as shown in this table. Offsets are relative to the address in bits 1 to 15 of the Eclipse accumulator referred to by the DOAS instruction initiating the transfer (see #5.2.1 and its subsections). Bit references are within words and are numbered 0 to 15. Zero (0) is the most significant (left-most) bit.

OFFSET	BITS	CONTENTS	PARAGRAPH
0	0-15	Base Sample Interval	#2.1, #5.2.2.1
1	0-3	Sample Ratio Exponent, Epoch 0	#2.3.2, #5.2.2.2.1
1	4-15	Epoch Interval Count, Epoch 0	#2.4.1, #5.2.2.2.2
2	0-3	Sample Ratio Exponent, Epoch 1	
2	4-15	Epoch Interval Count, Epoch 1	
3	0-3	Sample Ratio Exponent, Epoch 2	
3	4-15	Epoch Interval Count, Epoch 2	
4	0-3	Sample Ratio Exponent, Epoch 3	
4	4-15	Epoch Interval Count, Epoch 3	
5	0-3	Sample Ratio Exponent, Epoch 4	
5	4-15	Epoch Interval Count, Epoch 4	
6	0-3	Sample Ratio Exponent, Epoch 5	
6	4-15	Epoch Interval Count, Epoch 5	
7	0-3	Sample Ratio Exponent, Epoch 6	
7	4-15	Epoch Interval Count, Epoch 6	
8	0-7	Channel Specification	#1.3.2, #5.2.2.3
8	8-15	unused	
9	0-7	unused	
9	8-15	Header Word Number	#5.2.2.4
10	0-3	unused	
10	4-15	Fire Parameter	#12.4.1.1
11	0-3	unused	
11	4-15	Arm Parameter	#12.4.1.1

TABLE 2: Arrangement of Immediate Parameters in Eclipse Accumulators

The Immediate Parameters in Eclipse accumulators ready for transfer to the subsystem are arranged as shown in this table. Bit references are within words and are numbered 0 to 15. Zero (0) is the most significant (left-most) bit.

Parameter Address Word

BITS	CONTENTS	PARAGRAPHS
0	Select:	
	0 - Universal Parameter Transfer	#5.2.1
	1 - Diagnostic Register Transfer	#7.0
1-15	First Eclipse Memory Location	#5.3.2.1

Data Address Word

BITS	CONTENTS	PARAGRAPHS
0	unused	
1-15	First Eclipse Memory Location	#5.3.2.2

Control Word

BITS	CONTENTS	PARAGRAPHS
0	Mode Selection	#5.3.2.3.2
1-2	Data Channel Map Selector	#5.3.2.3.4
3	Parameter Interrupt Selection	#5.3.2.3.5
4	Sweep Interrupt Selection	#5.3.2.3.6
5	unused	
6	Output Trigger A Selection	#5.3.2.3.1
7	Output Trigger B Selection	#5.3.2.3.1
8	Output Trigger A Polarity	#5.3.2.3.8
9	Output Trigger B Polarity	#5.3.2.3.8
10-12	Trigger Location	#5.3.2.3.3
13-15	Epoch Number	#5.3.2.3.7

TABLE 3: Bit Usage in Subsystem Status 1

The bit references of Subsystem Status 1 described in section #8.2 are summarized. Bit references are within words and are numbered 0 to 15. Zero (0) is the most significant (left-most) bit.

BITS	CONTENTS	PARAGRAPHS
0-1	Transmission Complete, in particular (octal):	#8.2.13
	0 - illegal	
	1 - Universal Parameter	#5.2.1.5.2
	2 - Diagnoatic Register	#7.2.5.2
	3 - Sweep	#3.3.1
2	unused	
3	unused	
4	External Trigger Bit	#8.2.12
5	Point Not Stored	#8.2.11
6	External Trigger in Synchronous Mode	#8.2.10
7	Illegal Parameter	#8.2.9
8	Power Up	#8.2.8
9	Post-stimulus Trigger	#8.2.7
10	Incomplete Pre-stimulus Data	#8.2.6
11	Trigger Between Sweeps	#8.2.5
12	False Start	#8.2.4
13	Inappropriate Parameter Modification	#8.2.3
14	Subsystem Overrun	#8.2.2
15	ADC Not Ready	#8.2.1

TABLE 4: SYNCHRONOUS MODE -- EXAMPLE OF MEMORY ALLOCATION AND PARAMETERS

DATA IN ECLIPSE MEMORY

offset			
HEADER			
0	Subsystem Status 1		
1	Subsystem Status 2		
2	Software-Supplied Data 1		
3	Software-Supplied Data 2		
DIGITIZED DATA			
	epoch	point	chan
Pre-stimulus			
4	0	1	0
5			3
6			5
7		2	0
8			3
9			5
10	1	1	0
11			3
12			5
13		2	0
14			3
15			5
16		3	0
17			3
18			5
Trigger Point			
19	X	X	0
20			3
21			5
Post-stimulus			
22	2	1	0
23			3
24			5
25		2	0
26			3
27			5
28		3	0
29			3
30			5
31		4	0
32			3
33			5
34	3	1	0
35			3
36			5
37		2	0
38			3
39			5

SWEEP CHARACTERISTICS

Universal Parameter Loc. = 3000 (octal)
Data Storage Location = 4000 (octal)
Base Sample Interval = 10 microseconds
Number of Epochs = 4
Channels Selected = 0, 3 & 5
Header Length = 4
(2 words supplied by software)
Mode = Synchronous
Out. Trig. Select: both delivered
Out. Trig. Polarity: both positive
Trigger Location: before epoch 2
Data Channel Map: B
Parameter Interrupt: yes
Sweep Interrupt: yes
Fire Level: -5.00000 volts
Arm Level: -3.99902 volts

epoch	# pnts	sam int (microseconds)
0	2	80
1	3	40
2	4	10
3	2	20

UNIVERSAL PARAMETERS

offset	octal values
0	000012
1	030002
2	020003
3	000004
4	010002
5	000000
6	000000
7	000000
8	112000
9	000004
10	006000
11	006315

PARAMETER ADDRESS WORD (octal)
003000

DATA ADDRESS WORD (octal)
004000

CONTROL WORD (octal)
035424

TABLE 5: ASYNCHRONOUS MODE -- EXAMPLE OF MEMORY ALLOCATION AND PARAMETERS

DATA IN ECLIPSE MEMORY

offset				
HEADER				
0	Subsystem Status 1			
1	Subsystem Status 2			
2	Pre-stimulus Pointer = 2*			
3	Pre-stimulus Skew			
4	Software-Supplied Data 1			
5	Software-Supplied Data 2			
DIGITIZED DATA				
		epoch	point	chan
Pre-stimulus				
6		0	4	2
7				4
8			5	2
9				4
10			extra	2*
11				4
12			1	2
13				4
14			2	2
15				4
16			3	2
17				4
Trigger Point				
18		X	X	2
19				4
Post-stimulus				
20		1	1	2
21				4
22			2	2
23				4
24			3	2
25				4
26			4	2
27				4
28			5	2
29				4
30		2	1	2
31				4
32			2	2
33				4
34			3	2
35				4

SWEEP CHARACTERISTICS

Universal Parameter Loc. = 3000 (octal)
Data Storage Location = 4000 (octal)
Base Sample Interval = 10 microseconds
Number of Epochs = 3
Channels Selected = 2 & 4
Header Length = 6
(2 words supplied by software)
Mode = Asynchronous
Out. Trig. Select: none
Out. Trig. Polarity: both positive
Trigger Location: before epoch 1
Data Channel Map: B
Parameter Interrupt: yes
Sweep Interrupt: yes
Fire Level: +5.00000 volts
Arm Level: +3.99902 volts

epoch	# pnts	sam int (microseconds)
0	5	80
1	5	10
2	3	20

UNIVERSAL PARAMETERS

offset	octal value
0	000012
1	030005
2	000005
3	010003
4	000000
5	000000
6	000000
7	000000
8	024000
9	000006
10	002000
11	001463

PARAMETER ADDRESS WORD (octal)
003000

DATA ADDRESS WORD (octal)
004000

CONTROL WORD (octal)
134013

* In this sweep, the external trigger occurred while the subsystem was processing a point that was to be stored at displacements 10 and 11.

DA

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